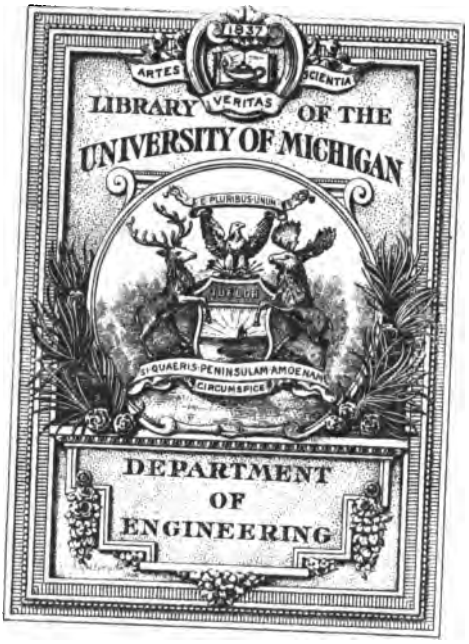
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1172 Issued June 25, 1909.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 215.

A. C. TRUE, Director.

IRRIGATION IN NEW MEXICO.

BY

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Territorial Engineer.

PREPARED UNDER THE DIRECTION OF

SAMUEL FORTIER,
Chief of Irrigation Investigations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., April 22, 1909.

SIR: I have the honor to transmit herewith a report on irrigation in New Mexico, prepared by Vernon L. Sullivan, Territorial engineer of that Territory. This is one of a series of reports giving the present status of irrigation in the several arid States and Territories. There is a very large call upon this Office for general information regarding the opportunities for settlement on irrigated lands in these States and Territories, the cost of land and water and of establishing homes on these lands, and regarding the crops grown. The attempt has been made to include in each of these reports as nearly as possible all the information which will be needed by parties contemplating settlement in the State or Territory to which it refers. It is recommended that the report be published as a bulletin of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INTRODUCTION.

The Territory of New Mexico formerly included parts of Colorado, Utah, and Texas, and all of Arizona. On March 2, 1867, the boundaries of New Mexico were fixed at 31° 20′ and 37° north latitude and the one hundred and third and one hundred and ninth meridians. The area of the Territory is 122,469 square miles, or 78,370,160 acres. (Pl. I.)

Grand chains of the Rocky Mountains traverse the Territory from north to south, but become scattered into short ranges as they progress into the central part. Between these numerous branching ranges are many valleys, watered by rivers flowing southward from the snow-capped mountains. Broad mesas and plains cover many thousand square miles above these river valleys. (Fig. 1.)

Owing to the large expanses of free range, the cattle industry has been a leading pursuit of the people for many years. To this was joined the raising of horses, sheep, and goats. With the influx of population many farms are taking the place of grazing grounds and the ranges are becoming more curtailed year by year.

New Mexico in mineral wealth equals neighboring States and Territories. It has, in common with southern Colorado, large deposits of copper, gold, silver, and coal. Big railway combines are being formed to develop the extensive coal fields of northern New Mexico. Although in one of the oldest parts of the United States, these large deposits of wealth have as yet hardly been tapped in real earnest, but now, with the westward movement, mines, smelters, and mining towns are being rapidly established. Mining, stock raising, the operations of railways, and agricultural pursuits occupy the attention of a large percentage of the population.

A very large portion, probably 50 per cent, of New Mexico's population is composed of the descendants of the old Spanish settlers, of Mexicans, and of Indians, while the percentage of immigrants from the Eastern States is yearly becoming larger. During the seventeen months ending November, 1907, homestead entries made by these new settlers numbered 23,000. The population of New Mexico is now

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larger than that of Idaho, Delaware, Nevada, or Wyoming. The centers of population lie along the river valleys, where farming is carried on, in mining towns, and along the railroads, where many thriving towns are springing up with great rapidity. The advent of capital and emigration from the East is beginning to diversify the

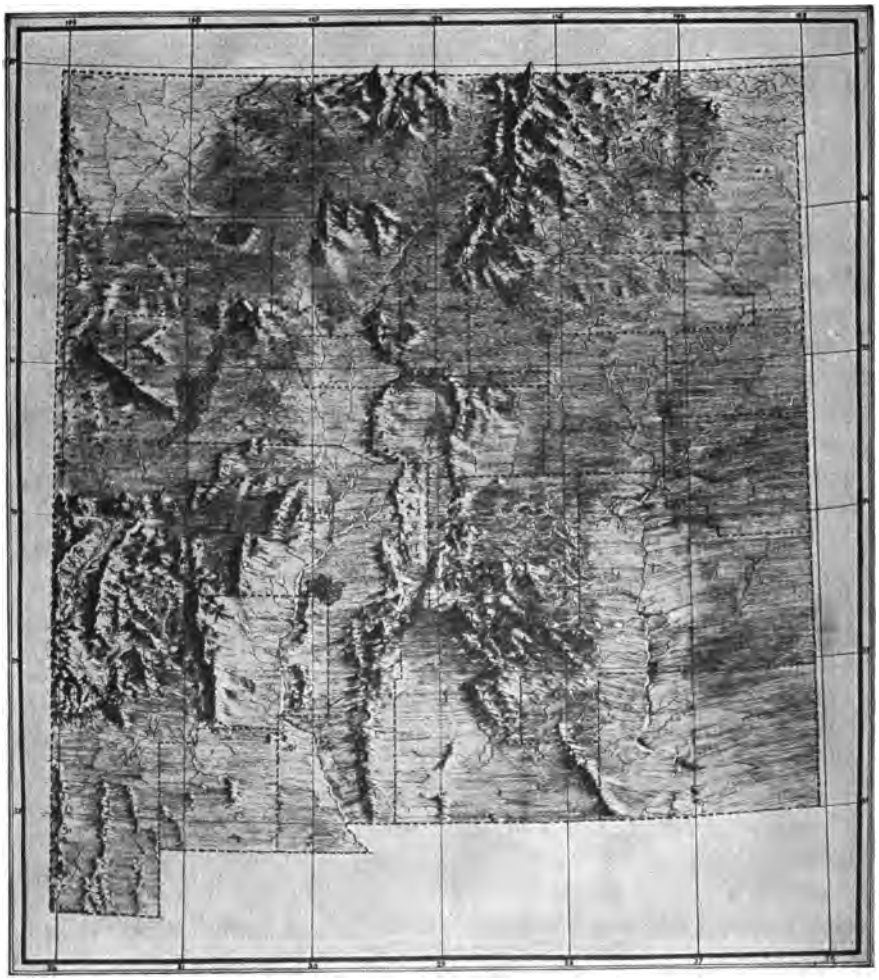

FIG. 1.—Relief map of New Mexico showing topography and streams. (Bull. No. 66, N. M. Agr. Expt. Sta.)

industries, so that now lumbering, mining, and agriculture, both with and without irrigation, are displacing the cowboy and the sheep herder, and even the first signs of manufacturing are apparent.

The assessed valuation of property in New Mexico, chiefly real estate, railroads, and live stock, amounts in all to about $51,807,788,

as shown by tax list of 1907, which is about 40 per cent of its real value.

With very few exceptions, all places of habitation can be reached by stage, automobile routes, or railroad. The principal railroad systems are the Atchison, Topeka and Santa Fe; the Pecos Valley; the Denver and Rio Grande; El Paso and Southwestern; the Rock Island; and the Southern Pacific. Running practically north and south, the Santa Fe enters the northern portion of the Territory at Raton and passes on to El Paso, Tex. Another portion of this system, connecting the western line with the eastern line, passes from Arizona through Gallup, Belen, and Albuquerque to the western part of the Texas Panhandle at Texico. The Pecos Valley line enters the Territory through Eddy County and continues north to Roswell, thence northeasterly out of New Mexico. The Denver and Rio Grande covers the extreme northwestern part; the Southern Pacific, the southwestern corner; and the El Paso and Southwestern, the eastern part between the Pecos and Rio Grande. The Santa Fe Central operates near the center of the Territory, and the St. Louis, Rocky Mountain and Pacific has about 100 miles of tracks in Colfax and Union counties. There is also a number of automobile lines connecting various portions with the railroads, the principal ones being the Torrance-Roswell and the Tucumcari-Melrose lines.

A great deal has justly been made of the climate of the "Sunshine Territory." The aridity of this portion of the United States contrasts with the humidity so disagreeable in the East and North. The prevalence of cloudless days has proven a boon to health seekers. While it is true that it gets quite warm, the temperature occasionally going up to 106° F., no great discomfort or inconvenience is experienced, and sunstrokes are unknown. It is to this important factor that New Mexico owes such phenomenal results in farming wherever water is applied.

The rainy season generally occurs during the months of July and August in the northern portions, but varies somewhat from these months in the south. The average rainfall is 10 to 20 inches. There are three small localities where an average of more than 25 inches falls—Chama, in Rio Arriba County; the western portion of Mora County; and Cloudcroft in Otero County—while the central part of McKinley, the western part of Socorro, and the eastern part of Quay, Roosevelt, Eddy, and Chaves counties have an average of over 20 inches. The mean yearly temperature ranges from 44° to 62° F., according to latitude and altitude, the southern part averaging near 62°; the northern and central parts near 44°. This rather low mean is due to the wide range between night and day temperatures. Thus

the temperature sometimes drops from 106° during the day to 40° before morning.

The first killing frost in the fall and the last in the spring in the southern part come in November and March, respectively; in the central section in October and April; and in the northern part in September and May. In the spring of 1907 there occurred a late killing frost on April 22, which completely destroyed many crops. This, however, was unusual, not having happened for twenty-five years, and was felt throughout most of the western part of the United States.

The following table, taken from the U. S. Weather Bureau reports, shows the mean annual rainfall and temperature in different sections of New Mexico for the years 1905, 1906, and 1907:

Mean annual rainfall and temperature at U. S. Weather Bureau stations, 1905–1907.

Station.	County.	Rainfall.				Temperature.			
		1905.	1906.	1907.	Average.	1905.	1906.	1907.	Average.
		Inches.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*
Alamogordo	Otero	19.52	11.16	10.88	13.85	59.9	60.7	61.4	61.0
Albuquerque	Bernalillo	.....	8.36	9.18	8.77	54.5	57.6	56.9	56.3
Fort Union	Mora	20.17	24.65	17.38	20.73	49.0	46.9	47.9	47.9
Fort Wingate	McKinley	21.21	22.96	19.17	21.11	48.7	49.6	49.6	49.3
Las Vegas	San Miguel	23.86	23.08	18.00	21.64	49.6	50.2	51.0	50.2
Lordsburg	Grant	19.50	9.58	12.15	13.74	60.6	61.4	62.6	61.5
Portales	Roosevelt	21.30	21.78	.....	21.54	60.6	61.4	62.6	61.5
Santa Fe	Santa Fe	17.22	16.60	15.15	16.32	47.7	48.5	48.9	48.3
Vermejo	Colfax	17.72	18.00	16.20	17.30	44.0	44.5	46.2	44.9
Roswell	Chaves	19.23	15.21	13.43	15.95	57.1	58.3	60.1	58.5

WATER RESOURCES.

New Mexico to-day is using but a small part of the water that may be made available for irrigation. As will be seen later, there is enough water flowing out of the Territory to irrigate 2,000,000 acres of land, provided all such unused water could be conserved, and in addition many acre-feet of water are lost through evaporation and seepage, never reaching the principal rivers. Numerous arroyos, or draws, discharge large quantities of water at times of flood. This spreads out over the valley below and seeps away or evaporates. No reason can be seen why all the available water of New Mexico can not be conserved eventually.

One peculiarity of the natural formation of this Territory is its broken stratification, causing a great many streams to disappear into the underflow. Much of the water that sinks may form sources of artesian supply, but a great deal of it is undoubtedly lost. The principal artesian basin is mainly embraced in the Pecos Valley between Roswell and Carlsbad, where thousands of acres are irrigated

from artesian wells. These wells hold out remarkably well, but as the number is increased the pressure is gradually diminishing, though during the nonirrigating season it again increases. In the artesian district reports of supervisors show that there were 323 wells in the early part of 1905, but by the middle of 1907 the number had increased to nearly 500, nearly all of which had a good flow.

Very little of the water available for power purposes is used at present. That which is used is mainly on the Pecos and Mora rivers. The former furnishes power for electric light, pumping of water, and other purposes, while on the Mora River the power is used exclusively for flour mills. There are power plants in various places, and many large power projects are still undeveloped, located principally on the following rivers and creeks: Pecos, Rio Grande, San Francisco, San Juan, Gila, Las Animas, and Penasco. Smaller opportunities are to be found on the Rayado, Santa Fe, Cimarron, Pueblo, Hondo, Ruidoso, La Luz, and Nambe rivers, besides feasible projects on other perennial mountain streams. On many of these power plants can be built cheaply, and in a great many cases every gallon of water used could pump several gallons from the underflow, thus increasing the water supply for irrigation, domestic, and stock purposes.

In nearly all the mountain districts spring and snow water of the purest quality can be had for the towns and villages, while in the lower valleys the water in some instances becomes alkaline and unfit for domestic use. None of the rivers is navigable.

Of the principal river systems of the Territory the Rio Grande is the largest. This long and important stream has its source in the Rocky Mountains in southern Colorado and northern New Mexico and flows south through the central part of the Territory. This river is a torrential stream in the southern part of the Territory, and while the minimum flow has been appropriated by direct diversion, there is a large amount of flood water that is not used beneficially. This flood water, however, will all be stored and distributed after the construction of the Elephant Butte, or Engle, reservoir by the United States Reclamation Service. After measurements extending over a period of many years the Reclamation Service has determined that there is sufficient water for 180,000 acres of land. The upper part of the river has a more constant flow, being fed the year round from snows, and the river is confined more in cañons, while in the southern part it flows through a broad, level valley with low, sloping banks. Consequently, at nearly every flood it changes its bed, doing great damage to property all along its course. The heads of all the ditches diverting water from this stream are more or less unstable, and often after floods the owners of ditches find that the river has shifted, leaving them without water.

The largest tributary of the Rio Grande, the Pecos, rises in the Rocky Mountains in northern New Mexico and flows southeast through the Territory, entering the Rio Grande in Texas. From the records of the Reclamation Service gauging station at Carlsbad it is calculated that at least 100,000 acre-feet flow annually unused from New Mexico. As this water comes in below the large storage reservoirs of the Carlsbad Reclamation project, it is subject to appropriation. There will be practically no available unappropriated water above the Carlsbad project if all the projects now contemplated by the Government and individuals are constructed. From this river, like many others, a part of the water disappears in the upper regions, but probably comes again to the surface lower down in the form of rivulets, springs, or artesian wells. No investigation has ever been made to trace the lost waters.

The San Juan River has the greatest discharge of any stream in the Territory. Rising in the Rockies of southern Colorado and northern New Mexico, it flows south into New Mexico and thence northwest into Utah, where it ultimately joins the Colorado. On June 6, 1907, a gauge was established at a point 20 miles above the mouth of the Las Animas River. The records of the Territorial engineer's office show a discharge at that place of 1,475,855 acre-feet for the year ended June 6, 1908; of this amount less than 30,000 acre-feet has been appropriated. We have no records to determine whether or not this discharge is normal. Considerable of this water is lost before reaching the Territorial line. This river flows in a deep, narrow valley, thus making it quite difficult to divert upon the large mesas along its sides.

The Las Animas River is another large river which rises in the mountains of Colorado and New Mexico. It flows south in the northwestern part of the Territory, entering the San Juan River near Farmington. From records of the year ended June 14, 1908, the discharge of this river at Aztec, 20 miles above its junction with the San Juan, was found to be 877,830 acre-feet. No previous records of water flow at this place have been taken. Although less than 50,000 acre-feet has been appropriated, practically all the water has been filed on for permits to appropriate. The maximum flow, caused by the melting snow, comes in May, June, and July, the time when water is most needed for irrigation. The deep, narrow valley is similar to that of the San Juan River.

The Gila River rises among the peaks of the Black Range, in the southwestern part of the Territory, and flows southwest. It has an estimated annual discharge of 400,000 acre-feet, mostly torrential water, of which only a small portion has been appropriated. Approximately 5,000 acres are irrigated at the present time from this

stream. A dam across the Gila canyon above Red Rock would form a large reservoir of sufficient capacity to conserve all its waters, including the largest floods, and sufficient land suitable for irrigation lies to the southeast, near Lordsburg.

The San Francisco River, also in the southwestern part of the Territory, rises in the Mogollon Range and flows south and then west into Arizona. The upper drainage area is a rugged country, but it broadens farther down into a narrow valley, averaging a half mile wide, where about 5,000 acres are irrigated. Very few data have been obtained concerning this stream. The estimated discharge is 50,000 acre-feet.

The Canadian River rises in the northeastern part of the Territory and flows south and east. Very few records of the discharge are available. However, it is estimated that there is at least 50,000 acre-feet per annum of unappropriated water in this river, largely flood water; hence storage would be needed. It is stated that there is a large practicable reservoir site northeast of Tucumcari.

In the lower part of Sierra County are the headwaters of the Mimbres River. This river flows south. All of the minimum flow of this stream has been appropriated, yet there are floods of considerable magnitude which, if stored, would probably irrigate 20,000 acres. One peculiarity of this stream is that all its waters, even in flood times, sink before leaving the Territory. There are many smaller streams in which the water disappears and does not, so far as is positively known, come to the surface again. In many places the water could be made available for appropriation by diverting above the point where it loses itself and conveying it in pipe lines to places of application.

All the streams in this Territory are more or less torrential or intermittent, the floods coming at different seasons of the year, but most of them in July. The necessity for storage becomes an important factor in conserving the water above the normal flow of each stream. It is quite important to construct equalizing reservoirs in order to distribute the water at such times as it is most needed for irrigation.

The following table shows approximately the average percentage of the total irrigation water applied in the different months:

Seasonal distribution of irrigation.

Month.	Per cent.	Month.	Per cent.
January	1	July	13
February	1	August	15
March	8	September	12
April	10	October	6
May	15	November	3
June	14	December	2

New Mexico has numerous basins which appear to be promising reservoir sites, some of them being very large. Great care, however, should be exercised and many investigations made regarding their ability to hold water. As has been mentioned, the stratification is often broken, leaving crevices for the water of the reservoir or canal to leak out, while in many other places are found beds of gypsum which, in contact with water, become soluble, causing serious leaks.

New Mexico is using very little of its underflow for irrigation except spouting artesian water, yet in many places there is a large underflow which can and will eventually be pumped to the surface. Mimbres, Estancia, Pecos, and Alamogordo valleys are especially favored in this way, and in some places cheap water power for pumping is available. In localities where water power is not at hand, crude oil or gas produced in central plants could be used to advantage. Light is thrown on this subject by the following statement by Ralph C. Ely, of Deming:

> Under present market conditions crude oil can be laid down in Deming in carload lots at 4.8 cents per gallon, a little less than $2.02 per barrel. The crude-oil engine has practically the same efficiency as a gasoline engine, developing about the same amount of power on a gallon of crude oil as a gasoline engine will generate from a gallon of gasoline or naphtha. It is perfectly safe to figure on a crude-oil consumption of seven-eighths of a pint per horsepower per hour, making the fuel cost per horsepower, under present market conditions, a very little over half a cent. To this, of course, must be added the cost of lubrication oils, attendance, repairs, and deterioration.

LANDS.

As the topography of New Mexico is distinguished by mountain ranges, high plateaus, and deep, narrow river valleys, except in the south, where weathering agencies have broadened the Rio Grande and Pecos valleys, the valley soils have been derived from the constituents of the neighboring hills. As the result of the raising and lowering of the earth's crust in this particular region, the rivers have built up valleys with their own deposits instead of cutting chasms and carrying the disintegrated material to the sea. These valleys are uniformly covered with a deep, rich soil, abundantly supplied with mineral plant foods and usually with plenty of humus. Experience has shown that the turning under of grasses and other herbage renders the soils of the valleys ideal for agricultural purposes. The soil varies from a reddish, sandy loam to an occasional adobe, thus being particularly adapted to irrigation.

The following extract from a letter of J. D. Tinsley, soil expert of the New Mexico Experiment Station, describes certain soils in north-

central New Mexico, but applies generally to the soils of the Territory, excepting in the older river valleys:

The soils in the vicinity of ——— are practically all alluvial, having been derived from the rocks of the surrounding mountains and mesas. As there is a great deal of lava rock in that part of the country, the decomposition of this rock has contributed materially to the soil formation. Soils derived from volcanic rocks are usually fertile, being rich in potash and phosphoric acid, and this seems to be the case with the soils of that district. In their virgin state they are fairly well supplied with humus that is rich in nitrogen, and their nitrogen contents can be easily maintained and increased by the use of leguminous crops, such as peas and alfalfa, in a crop rotation.

The texture of the soil on the higher land is sandy loam to loam, and this is usually underlaid by clay or clay loam, which gives the soil a good capacity for storing water. The light texture of the surface makes it easy to produce a soil mulch for the purpose of retaining the soil moisture.

The soil of the draws and basins is usually rather heavy in texture, clay loam to clay, but when carefully worked it breaks up nicely. When these soils are worked too wet or too dry they break up cloddy and are not so easily reduced to a good condition of tilth.

The soils of this district, wherever cultivated, have proven their productiveness for all of the crops for which the climatic conditions are best adapted. The elevation and the proximity of the high mountains give a cool climate, especially at night, and this determines the character of the crops grown. Alfalfa gives three cuttings per year. The climate is a little warm for the best development of the Colorado field peas. The short-season varieties of Indian corn do well, and it should be possible to materially increase the present yield of corn by selective breedings.

The mountain sides, through centuries of erosion, become shallow-soiled or rocky and are covered with piñon, pine, and cedar.

About 400,000 acres are irrigated at the present time, with additional 100,000 under a few ditch systems ready for settlement. Colfax County has probably a larger area under ditch subject to irrigation than any other county. The Farmers' Development Company of Springer has several thousand acres under ditch. The French Land and Irrigation Company of the same place also has considerable land ready for settlement. One advantage of this part of the country is that the rainfall is heavy enough to raise a fair crop if properly cultivated without irrigation, and the amount of water needed for irrigation is, therefore, very small.

There are several thousand acres of land awaiting the application of water at Carlsbad, where the works of the Carlsbad project are now completed and water is ready for delivery. Among the projects completed, or nearly so, in the Rio Grande Valley the Elmendorf project has several thousand acres ready for the application of water at Elmendorf, and the Bluewater Development Company of Albuquerque has part of its works completed and is ready to deliver water

to a portion of its land. Small projects ranging from 100 acres up are scattered over the entire Territory.

New Mexico has an area of approximately 70,000,000 acres. The lands can be classified into grants, Indian reservations, National Forests, and Government and Territorial lands, and for convenience each will be taken up separately.

GRANTS.

There are about one hundred and fifty land grants, large tracts of land that have been granted by Congress to private individuals or corporations to confirm holdings made before the Territory came into the possession of the United States. A few of the claims overlap each other, so that 9,900,000 acres confirmed by Congress represent an actual acreage of 8,800,000. About 500,000 acres of first-class marketable timber will be found; 400,000 that are irrigated or suitable for irrigation, of which perhaps 100,000 acres are already in cultivation; 2,500,000 acres suitable for dry farming; 5,000,000 acres fit for grazing; and 400,000 acres that can be called waste land, being made up of canyons with land too steep for grazing or farming.

INDIAN RESERVATIONS.

Divided among four Indian reservations is an acreage of 5,700,000 acres of land, of which 300,000 acres are good timber, 500,000 adapted for dry farming, about 800,000 acres can be irrigated, 4,000,000 acres suitable for grazing, and probably 100,000 acres of waste land.

NATIONAL FORESTS.

The eleven National Forests in the Territory cover some 8,500,000 acres of the best timber sections. Of this amount 500,000 acres are made up of fine timber and 1,000,000 acres of dry-farming land, 100,000 acres are capable of irrigation, 6,500,000 acres are good for grazing, and 400,000 acres are waste land.

GOVERNMENT AND TERRITORIAL LANDS.

Outside of the land grants, Indian reservations, and National Forests there are about 47,000,000 acres belonging to the United States and the Territory, or already patented or filed on. Of this area 350,000 acres are good timber, 700,000 acres are or can be irrigated, 6,500,000 acres are suitable for dry farming, 36,000,000 acres are grazing land, and 3,000,000 acres are waste land. Of the foregoing there are about 5,000,000 acres of Territorial lands and about 3,500,000 acres of land either patented by the Government or covered by filings.

PRODUCTS OF IRRIGATED LANDS.

For many years the production of alfalfa has been the predominant agricultural enterprise on account of the little labor required, as it needs only one or two irrigations per cutting. During the earlier settlement cereals were much grown and are still raised with success. Wheat and corn can be grown throughout the Territory, even in the driest dry-farming districts. While oats weigh but from 30 to 32 pounds per bushel in the East, when grown in the Southwest a bushel weighs 38 to 40 pounds; wheat weighs 60 pounds a bushel in the East, as compared with 70 to 72 pounds in New Mexico when grown under irrigation. Around towns and cities intensive farming is practiced. All the common vegetables, melons, and fruit are grown. Recently a company of Rockyford, Colo., has become interested in the southern Rio Grande Valley and about 500 acres of cantaloupes, as a starter, have been planted. These melons, reaching the markets at a time between those raised in California and the Rockyford product and being of exceptional quality, find ready sale in the East and give substantial returns, netting the grower $75 to $300 per acre.

A corporation has recently been organized for the purpose of introducing sugar beets into New Mexico on a large scale. The fields are south of Albuquerque. The Pecos Valley and the Cimarron country are also particularly adapted to beet production. Beets raised in the abundant sunshine and with the soil advantages of the Southwest contain a very large percentage of sugar. The product will doubtless be sold, as in northern Colorado, to sugar factories at $5 per ton. The crop of 10 to 30 tons an acre raised in Colorado will without doubt be equaled here, if not exceeded.

Alfalfa from the southern part of the Territory finds a sure and ready market in El Paso; that from the northern and eastern sections, in the cities on the Mississippi. In many localities, especially in the south, four cuttings and grazing for stock on the aftergrowth are obtained. The yield of hay in this part of the United States is 2 to 7 tons an acre when grown under irrigation; an average of 5 tons is a conservative estimate, usually producing a net return of $10 a ton.

The grain raised, while not extensive, generally pays large returns per acre. Corn produces 50 to 80 bushels and finds a ready market at the present high prices. Wheat produces about 40 bushels when irrigated.

Cotton, of recent introduction in the Pecos Valley near Carlsbad, is doing well. The yield is good and the fiber is long. When setting out young orchards the practice is to fill in the rows with cotton plants, so that by irrigating the cotton a slow, deep irrigation will be secured for the roots of the trees, thus enabling them to penetrate

deeper and deeper into the soil. One prominent irrigator sold the seed and 35 bales of cotton thus grown for $2,004; the actual space occupied by the cotton in the orchard was 28 acres.

By far the best paying crop is fruit. The conditions in New Mexico are perfect for its production. The warm climate with cold nights produces fruit that is exceptional in soundness and in flavor, consequently a fine shipper. Those portions of New Mexico which escaped the frost of last year made large returns on fruit, owing to the high prices. As high as $1,300 an acre was received in one locality. Bartlett pears are raised in preference to other fruits, but grapes, peaches, plums, and in fact all kinds of fruits, except tropical and citrus fruits, can be raised with irrigation.

Crops are marketed in Kansas City, Denver, Chicago, El Paso, and elsewhere. The home market is generally good, owing to the number of mining camps.

The New Mexico Experiment Station at Mesilla Park has conducted experiments with remarkable results. Fabian Garcia, the horticulturist, has produced Bermuda onions of shipping quality that run as high as 60,000 pounds to the acre. These, being grown on experimental plats, were of course fertilized with sodium nitrate and had careful attention. At 2 cents a pound they show a gross return of $1,200.

The irrigated crops having been described in a general way, a short statement regarding nonirrigated crops will be made. New Mexico has quite a large area above the river bottoms where the rainfall is sufficient to mature cereal crops. The best known dry-farming district is the vicinity of Las Vegas, where W. H. Campbell has inaugurated a system by which good results have been secured. Eastern and northern New Mexico are also well adapted for dry farming. The crops adapted to these conditions are the common cereals, sorghum, millet, legumes, vegetables, and cotton. Of course, there are types of each that can not be grown without more water than the precipitation affords.

There can be no surer crops than those grown under irrigation where irrigation is necessary. There are no losses from rains coming during the harvesting period. Irrigation means the application of sufficient moisture at the proper time, thereby producing a maximum yield, and the crop thus produced has the largest possible amount of nutrients, afforded by the perfect soil conditions obtained by the intelligent use of water. There is naturally more work, and farming becomes more scientific. In rainfall farming one is obliged to dispense with one essential condition of uniform and perfect growth—control of moisture. With proper drainage the water-soaked condition of the soil caused by too heavy and too frequent rains can be avoided and

the soil rid of water coming at undesirable periods of the year. Yet natural precipitation never can produce the ideal conditions for the growth and sustenance of crops which are almost absolutely at the command of the experienced irrigator who has sufficient water at the proper time. Experience has shown, however, that very few of the irrigating farmers know how to bring about the ideal conditions. As previously suggested, irrigation farming is more scientific and intricate than is generally conceded.

HISTORY OF IRRIGATION DEVELOPMENT.

The Spaniards entered the valley of the Rio Grande before the middle of the sixteenth century and found there the Pueblo Indians, living in many-storied towns and cultivating the land of the valleys, upon which they brought water by acequias, or irrigating ditches, many of which are still in use. How long these Indians had been there is unknown, for they were then old inhabitants. They raised not only grain and fruit, but perhaps flowers, as one homesick Spaniard wrote that flowers bloomed like the roses of Aragon along the acequia banks. There are seventeen or eighteen settlements of Pueblo Indians in New Mexico, each holding a land grant 2 leagues square, and, with its old pueblo, containing 200 to 600 people. There was at least this number of pueblos when the Spaniards came to the country, probably several more, as the ruins of three or four have been found. The inhabitants of the pueblos were, moreover, much more numerous than now. There must have been 15,000 to 20,000 people living on products raised by irrigation in the Rio Grande drainage basin above the Journado del Muerto, and the area of irrigated land probably exceeded 30,000 acres.

Irrigation in New Mexico is therefore no new thing. It was carried on without doubt centuries ago by the Aztecs in the northwestern part of the Territory, in what is now San Juan County. There are traces of a small ditch, several miles long, which headed on the Las Animas River and conveyed water to the Aztec village, the ruins of which are still visible about a mile west of Aztec. The walls remaining indicate that the buildings, made of stones and mud, were at least three stories high. The rooms, about 14 feet square, were connected, forming a square with the south side left open, leaving a space in the center containing two circular reservoirs, water for which was supplied by the ditch described.

Though a large native American population has come into the Rio Grande Valley since the construction of railroads in 1880, it is confined principally to the towns, and to-day a large percentage of the irrigating is done by Mexicans and Indians. These people pursue their ancient methods of irrigation, unaffected by modern progress.

When American enterprise asserted itself the Pecos Valley was perhaps the first part of New Mexico to take up irrigation on a larger scale. Here large, strong dams were built, forming huge reservoirs 5 to 6 miles long and 2 to 3 miles wide for the storage of water, which at that time rivaled any other works constructed for such purposes in the United States. Canals 40 miles long were built, and water was conveyed across rivers in large flumes. Many acres were put under irrigation with more or less success. One of the greatest drawbacks was the lack of knowledge of how to handle the water and soil. Some farmers had the best success, while others failed. A great proportion of the farmers came from a rainfall country, where farming is carried on in an entirely different manner, with the result in many cases of their overindulging in a good thing, drowning out the crops and water-logging their own soil as well as their neighbors' below them. The success of the farmers increased as they gained knowledge along these lines.

Irrigation activity soon began to develop in Colfax County and neighboring districts. The Maxwell Land Grant Company has a number of reservoirs and impounds considerable water. Concerning this district Mr. Harroun, the engineer employed by the International Boundary Commission, says:

> The land irrigated under these systems is about as follows: One thousand acres under the small ditches along the Cimarron bottom, 500 acres under the Ponil ditches, 1,000 acres under the Rayado ditches, 2,000 acres under the Maxwell Company's ditch, and 2,500 acres under the Springer ranch.

In 1897 the legislative assembly created a commission to look into, investigate, and report on the irrigation conditions, and the efficiency of the laws governing the same then existing throughout New Mexico. This body consisted of five members. The report of this commission presented the irrigation and water-supply questions better than any previous publication upon that subject. However, hardly any encouragement was given to framing new and better laws to govern the distribution of water. The report included the report of the expert engineer employed, and as a whole was adverse to laws putting rights upon a sound and legitimate working basis. These two parts very plainly conflicted, one claiming that the general law was sufficient, the other declaring the need of a code for the equitable distribution of waters. This state of affairs seemed to suffice until 1905, when an irrigation law creating the office of Territorial irrigation engineer was passed by the legislature. This was the first step toward placing the water supply under the direct supervision of a Territorial officer.

In 1907 the present irrigation code was passed, it being a very careful compilation of the laws of the several arid States. Under

this law irrigation has increased wonderfully through the enlistment of eastern money and enterprise. From March 19, 1907, to the present time applications covering over 2,000,000 acres of land have been filed in the Territorial engineer's office. The protection of law gives a sounder working basis for investment and development.

IRRIGATION ENTERPRISES.

Irrigation practiced on a scale sufficient to raise products for more than local consumption was scarcely known in New Mexico previous to the coming of the settlers from the overcrowded and worked-out farming districts of the Eastern States. Where produce was raised merely for the livelihood of one's family and possibly a little to be saved for a rainy day, to-day are found large fields of grain, extensive fruit orchards, fields of cantaloupes, sugar beets, and cotton, the aim being to supply the demands of other markets than those of the immediate vicinity. The activity of the new settlers has not yet become fixed. The capital invested in irrigation enterprises started on the large grants has not yet received the expected returns. It takes time to get returns from a thousand acres placed under water. Ditches must be dug, reservoirs for equalizing the flow of torrential streams must be constructed, and the land must be taken up by the small farmer before a new country assumes a farming appearance. It is safe to say that all the land now covered by approved applications for water will receive water in the next five years. When it is considered that only a little over a year and a half has been devoted to development under the supervision of the Territory, this indeed indicates progress.

While there have been filed in the Territorial engineer's office within the past two years applications sufficient, if completed, to successfully irrigate 1,500,000 acres of land, there are probably only a score of private enterprises in operation. These would show the actual growth of irrigation in New Mexico in enterprise, capital invested, and results obtained. A brief description of a few such companies follows.

PRIVATE ENTERPRISES.

The Maxwell Irrigated Land Company of Maxwell City owns a block of about 22,000 acres, adjoining that city on the west. The company has also acquired all the stock of the Vermejo Ditch Company, which held the oldest water rights on the Vermejo River. The land is probably the richest in the Maxwell grant and was picked out by the officers and engineers of the company as the choicest land for farming and irrigation purposes. This company owns reservoir

sites about 1,500 acres in superficial area, and has in partial operation 40 or 50 miles of ditches and laterals. Recently $50,000 has been expended in enlarging the low line system No. 5 to a capacity of about 300 cubic feet per second. The company claims to have data to warrant the expectation that water will probably be available for 20,000 acres. Water is being supplied this year to the Maxwell farm, containing 3,840 acres, and to farm lands on the property covering 3,000 acres or more. The soil is good.

The first large company to undertake the reclamation of arid lands in the Territory on a very large scale was the Pecos Irrigation and Improvement Company, which carried out two large irrigation enterprises in the lower Pecos Valley. The lower one later became the property of the Pecos Irrigation Company, and afterwards was sold to the United States. The upper one, now known as the Northern Canal, became the property of J. J. Hagerman, and is now owned by the water users under the canal.

The lower project was started about 1890, and when constructed comprised about 60 miles of irrigating canals and two large storage reservoirs, having a capacity of over 100,000 acre-feet. In 1893 a flood, aggregating about 45,000 cubic feet per second, occurred and washed out one of the smallest storage and diverting dams. In order to save the other dam a long embankment was blown out, lowering the spilling point 10 or 12 feet. This sacrifice saved the larger part of the works. Afterwards the dam that had been entirely washed out was rebuilt, and in 1904 there was in actual cultivation, under irrigation, over 13,000 acres, when a still larger flood of about 80,000 cubic feet per second again washed out the lower dam, a great loss to the company. Soon after this the company sold out to the United States Government, and the revived and amplified enterprise is now known as the Carlsbad project.

The Northern Canal derives its supply of water from the Hondo River near its mouth and has about 30 miles of canal in operation, successfully irrigating some 8,000 acres of the most fertile soil in the Territory. The duty of water here, it may be asserted, is 200 acres per cubic foot per second, which shows the character and intelligence of the farmers in this locality. There is probably, on account of the heat, more evaporation in this district than elsewhere, making this duty of water much higher than it seems. This community is one of the most prosperous in New Mexico, all its members doing well financially. The usual crops, such as alfalfa, fruit, and grain, are raised.

The Farmers' Development Company of Springer came into control of 18,000 acres of ranch land west of that town in 1906 and at once took steps to put about 10,000 acres under irrigation. The actual

work of construction was begun in August, 1907, and pushed vigorously, so that now reservoir No. 2, with inlet and outlet canals, is completed and in full working order. The construction involved the expenditure of about $80,000. The main dam of the reservoir is 1,100 feet long, 200 feet wide at the base, and 45 feet high. It was constructed in layers of selected earth 8 inches thick, and each layer was thoroughly puddled and rolled. The outlet consists of a line of 30-inch vitrified pipe laid in concrete. The capacity of this reservoir is 2,500 acre-feet. The basin is in the Heck Arroyo, from which it draws a portion of its water supply. The larger part of its supply, however, comes from the Rayado River through an inlet canal 1¼ miles long, which has a capacity of 250 cubic feet per second. There are 35 families living on farms receiving water from this system. The ground having just been broken, the main crop in 1908 was oats. Attractive dwellings have been built and the new post-office town of Miami has been established upon the tract, also a new school district for the benefit of the settlers. The company contemplates enlarging its service by the construction of additional reservoirs. The quantity and quality of water and soil and the climatic conditions are such that this section should become one of the leading agricultural districts of the Territory. The large beet-sugar companies of Colorado are displaying a great deal of interest in the district.

One of the most extensive irrigation enterprises in New Mexico is now under construction in Colfax County. This project contemplates the reclamation of 41,000 acres of land that has been acquired by the French Land and Irrigation Company. The land to be irrigated lies on the Atchison, Topeka and Santa Fe, El Paso and Southwestern, and the St. Louis, Rocky Mountain and Pacific railways. A system of seven reservoirs is intended which, by filling twice each season, will provide 129,000 acre-feet. All head-gate works, drops, diversion weirs, outlet tunnels, sand gates, spillways, and siphons are designed for reenforced concrete construction, and the head gates are all to be of the very best steel and modern in every way. The soil is rich, being an alluvial deposit 3 to 10 feet deep, of dark chocolate or black color. The cultivation of alfalfa, wheat, oats, barley, sugar beets, vegetables, apples, plums, and cherries, for which this district seems especially adapted, will create a prosperous community.

The Bluewater Development Company of Albuquerque controls the Bluewater and San Mateo valleys, comprising about 21,000 acres, situated 107 miles west of Albuquerque on the main line of the Santa Fe Railroad, there being two railroad stations within these valleys—Bluewater and Toltec. The lands are watered from an immense storage reservoir with a total capacity, when completed, of 92,000

acre-feet. The reservoir is located about 12 miles from the valleys and drains over 240 square miles of heavily timbered watershed. Water is now impounded in this reservoir, and many miles of canals have been constructed in the valleys. The outlet of the reservoir is a tunnel approximately 400 feet long and 6 feet square in section, driven through the solid rock at one side of the reservoir and not connected in any way with the dam. The reservoir dam is 386 feet long, and when it reaches its full height will be 100 feet above the datum line. The first section is already completed.

The Socorro Company of Elmendorf has made marked progress in its irrigation undertaking during the last year. It now has about 2,000 acres of land plowed and the rest is being prepared as rapidly as possible. They have this year (1908) about 50 acres of sugar beets which are doing well, some barley, and are planting alfalfa and summer crops as rapidly as possible. As this is the first year that crops have been planted, and as the ditch was not ready for water till May 5, this is only a beginning. The company intends from now on to push the work forward rapidly on the west side of the river, and will soon begin the construction of the east-side ditch system, with which it expects to irrigate about 20,000 acres.

The foregoing are the largest irrigation enterprises in actual use. The following enterprises have not, at this time, supplied water for irrigation but are making rapid strides in that direction: The Eden Land and Power Company of Aztec owns and controls the Eden Canal, a project which, when successfully completed, will be a good example of engineering skill. Water is taken from the Las Animas River, a stream which has its head in mountains 14,000 feet high. The source of supply is thus exceptionally steady and certain. The yearly discharge of the Las Animas River is large and is shown on a preceding page (p. 12). One cubic foot per second of water can easily be made to irrigate 100 acres, if not more, in this region. The main canal of this company is 35 miles long, and there are two other canals, of 10 and 15 miles, respectively. These will carry about 300 cubic feet per second. At one point in this company's system there occurs a drop of about 50 feet, making possible the generation of 400 horsepower, and if the water capacity of the ditch be extended by expending, say, $20,000, this power could be raised to 3,000 horsepower. It is the intention to furnish water for domestic, fire, light, and power purposes to present and future towns. The possibilities of this enterprise are many, and if carried to completion should aid largely in the development of the northwestern part of the Territory.

The Turley-Hollister project, located in the central part of San Juan County and deriving its water supply from the San Juan River,

is one of the largest enterprises of this kind that have ever been undertaken in the United States.

The records of water supply in the Territorial engineer's office show that the discharge of San Juan River in 1907 aggregated 1,475,855 acre-feet, and there is approximately 1,000,000 acres of the very best red, sandy loam soil situated below the proposed alignment of the ditch. The capacity of the reservoir involved in this proposition is over 1,000,000 acre-feet. With the exception of possibly 5,000 acres, all is Government land, a large portion, however, being inside the boundaries of the Navajo Reservation.

The topography and character of the soil are most ideal for irrigation, the land lying mostly on sloping mesas, with arroyos at suitable intervals, giving ample chance for proper drainage. The soils of these mesas have a characteristic reddish color, which is probably due to the iron derived from the higher sandstone mesas. The soil varies considerably in density in different localities, but the surface soil is never heavier than a loam. Wherever the soil has been raked it shows a loam to a clay loam, with a sandy surface underlaid by heavier soil, which affords perfect conditions for the conservation of moisture. The climatic conditions, together with the soil, are adapted to the production of a great variety of crops, including cereals, legumes, and fruits. Owing to the topographical conditions of these mesas late killing frosts in the spring seldom occur, hence this section is particularly suited for the fruit industry, the apple doing better than any other fruit.

In addition to the above project, the same parties have another in San Juan County which will divert water out of the Las Animas River in Colorado for the irrigation of about 130,000 acres in New Mexico. This project can be extended so as to cover nearly 700,000 acres if the water supply will warrant. The construction of this project is expensive, owing to the topographical conditions, but when once constructed it will bring under cultivation some of the most fertile land in the Territory. The other natural conditions are similar to the Turley-Hollister project on the San Juan.

One of the less known projects is located in the south-central portion of the Territory, where there has been no previous development, and is called the Gage and Endfield irrigation enterprise. This project diverts the flood water of the Sacramento River, which rises in the Sacramento Mountains, and carries it by canal several miles to a natural site for a large reservoir on the plain, where it is stored for the irrigation of a large tract of Government land below.

Among the best storage projects in New Mexico are the Cimarron, Ponil, and Verjemo reservoir enterprises of Charles Springer, of

Cimarron. The reservoirs are situated in the mountains, where the natural conditions are such that large capacities can be obtained, with the further advantage that owing to the high altitude and the fact that the reservoirs are deep the loss by evaporation is at its minimum, and the water can be used on the higher mesas, where the evaporation is less and the rainfall greater than below, thus gaining a higher duty from the water and at the same time applying it to lands where the return water will reach the rivers at points where it may be used again for irrigation. The writer is of the opinion that the greatest duty of water can be obtained by using it on lands nearest the source, thereby not only economizing it best in the first use, but also permitting the use of the return water several times over.

The Cimarron project, known also as the Eagles Nest project, has probably the best reservoir site in New Mexico. The Cimarron River, after passing through the mountains, enters a narrow valley with high mountains on every side. At first this would seem to be a complete lake basin, but the river cuts its way out through a narrow canyon. At this place a dam is to be constructed 130 feet high, impounding 113,700 acre-feet, for the irrigation of 65,000 acres. The estimated cost of the work is $100,000.

The manager of the Uracca Ranch Company of Cimarron is constructing a large irrigation enterprise, probably the largest in the Territory undertaken single handed. This project contemplates the storage of flood waters from Cimarroncito Creek. The water is conveyed through a canal ½ mile long and with a large capacity to a reservoir. By the construction of a storage dam about 50 feet high and 600 feet long this water will be held until it is needed for irrigation on the lands of the Uracca ranch.

The Rio Puerco Company's project on the Rio Puerco is the rebuilding of works partly completed a few years ago which excessive floods washed out. This project received its water supply from the Puerco River, and has for its purpose the irrigation of about 19,000 acres of land in the Bernabe Montano grant.

The Defiance reservoir project in the western part of McKinley County will derive its water supply from the Puerco River of the West. The principal feature of this project is the construction of a storage reservoir with a capacity of 20,000 acre-feet, bringing under irrigation 19,000 acres near Gallup, in a locality where there has been practically no irrigation development. The extensive mining interests in this section offer a good home market for agricultural products.

Another important private irrigation enterprise is that now under construction by the Palo Blanco Land and Irrigation Company. It

will easily irrigate 8,000 acres of fertile land in Colfax and Union counties. The company claims that the drainage area of the Palo Blanco Creek affords a constant flow in the stream, and that it is sufficient during flood times, if the volume is properly stored, to irrigate 12,000 to 15,000 acres. In the construction of the storage reservoir two dams are required. The first one, across Palo Blanco Creek, is 885 feet long and 58 feet high at its greatest height. The second dam is 1,700 feet long, with a height of 48.6 feet. The capacity of the reservoir is 7,500 acre-feet. Construction of the dam was begun in the fall of 1907.

The location of the project of the Red River Land and Water Company of Denver, Colo., is about 25 miles north of Taos. All the lands to be irrigated are of a very level character, with deep and very fertile soil. There is practically no waste land on the slopes. The altitude is about 7,000 feet, but apples, pears, and plums have been raised in this district with marked success. The water is to be taken from the Red River, a tributary of the Rio Grande.

The possible construction of a large storage reservoir on the Gila River, previously mentioned, has been taken up by the Gila Farm Company, of Gila, N. Mex. The application and maps covering this proposition have been filed in the Territorial engineer's office, and contemplate the construction of a dam 500 feet high backing water over an area of about double that of the U. S. Elephant Butte reservoir and about three times the size of the Assuan reservoir in Egypt. The area of land under this project is 5,256,800 acres.

A number of systems are in operation or contemplated along the main rivers, carried out on a community basis. Enterprising farmers organize in a particular locality and construct a system of canals for the benefit of their neighboring farms. The administration is similar to that of the old acequias or community ditches built by the early settlers, the cost of maintenance being borne by the individuals in proportion to the acreage benefited.

The Citizens' Ditch and Irrigation Company, as its name suggests, is operated on the community plan. This company is now constructing a canal to reclaim some 7,000 acres of choice fruit land in San Juan County. The water is derived from the San Juan River, near Blanco. The supply is ample for domestic, power, and irrigation purposes. The company has a permit to appropriate 100 cubic feet per second of water, approved by the engineer under the New Mexico laws. The canal at the head will be 14 feet wide, narrowing to 6 feet at the end, some 26 miles distant. Very little, if any, Government land subject to entry lies under this canal. Deeded land and relinquishments can be obtained at a very reasonable price, and

to members of the company water will cost about $25 per acre. The land lies within 8 miles of Aztec, the county seat, situated on the Denver and Rio Grande Railway.

Another community proposition is the project of Young & Norton, the purpose of which is to irrigate with flood waters of the La Plata River 5,000 or 6,000 acres in the western part of San Juan County, known as The Meadows. The water is to be diverted from the river by a ditch to an excellent reservoir site, where the flood waters are stored for the irrigation of lands below. The soil is good and the lay of the land, a nearly level mesa, is ideal for irrigation. This land has been taken up by individual farmers, the object being to irrigate through this project. The land was formerly withheld from entry by the Government in connection with its Las Animas-La Plata project, but was thrown open to entry on September 1, 1907, when the land was immediately entered upon by the parties now purposing to carry out this fine project.

Besides the projects mentioned above, there are about a hundred smaller ones scattered through nearly all of the counties of the Territory.

Efforts have been made to have the provisions of the Carey Act applied to New Mexico, but these efforts have failed so far.

RECLAMATION SERVICE.

The work of the Reclamation Service in New Mexico is of the utmost importance in the development of the arid West. The Government has five projects which have an acreage under them amounting to 210,000 acres, not including the continuation of one of these projects in Texas and Mexico. A description of these projects, based on that of W. M. Reed, district engineer in charge of the New Mexico reclamation work, is embodied here.

HONDO PROJECT.

The Hondo project is situated in Chaves County, townships 10 to 13 south, and ranges 22 to 25 east of the New Mexico principal meridian. Its latitude is 33°, longitude 104°, with an altitude of 3,900 feet. In its immediate vicinity the Eastern Railway of New Mexico, the Chicago, Rock Island and Pacific, and the Santa Fe railroads are available, thereby opening the district directly to the markets of Roswell, Amarillo, Fort Worth, and Chicago.

The land to be irrigated under this project extends from the headworks south to the outskirts of Roswell, a distance of 12 miles, and comprises an irrigable area of 10,000 acres. The land is all in private ownership with a farm unit of 160 acres. These lands have mostly a

fertile alluvial soil and range in price from $80 to $150 an acre. With a range of temperature from 10° to 100° F. the principal products are alfalfa, corn, fruits, and vegetables.

This section of New Mexico has a fair rainfall, about 18 inches, and the water supply for irrigation from the Hondo River should be of the best. The watershed area is 1,037 square miles, with an estimated annual run-off available for storage of 40,000 acre-feet. The duty of water is conceded to be 2½ acre-feet per acre per annum. The size of the Hondo reservoir is 1,910 acres, with a capacity of 40,000 acre-feet. The dams and embankments of the reservoir are earth fill. The total length of the main canal is 10.2 miles; length of distributing laterals, 20.2 miles.

Surveys to determine the feasibility of this project were begun in January, 1903, only about six months after the passage of the reclamation act. Construction was authorized on November 10, 1903, and bids were opened on September 6, 1904. After reletting a portion of the work, on the failure of one of the contractors and doing a portion by force account, it was completed in the summer of 1906. Unusual drought conditions have prevailed since the completion, and practically no water has been stored. Available water has been applied direct to the lands through the canal and lateral system, and about 1,500 acres are in cultivation at present, the crops being fruit, alfalfa, and grain. It is hoped and expected that at the end of the extreme drought the entire 10,000 acres will be cultivated in a very short time. Three hundred and sixty thousand dollars has been spent on this project.

CARLSBAD PROJECT.

The Carlsbad project was purchased by the Reclamation Service in 1905 from the Pecos Irrigation Company. The unprecedented flood of 1904 completely destroyed the diversion works of the Pecos company and forced it to sell. A detailed description of this enterprise has been given (see p. 22).

The following is quoted from the letter of Mr. W. M. Reed, district engineer in charge of New Mexico reclamation works:

Avalon dam destroyed 1904; surveys began by United States Reclamation Service, January, 1905.

August 28, 1905, a consulting board recommended that $600,000 of the Reclamation Service funds be allotted to this project for purchase of old company's holdings and reconstruction.

April 12, 1906, date set for opening bids. No bids submitted. April 18, 1906, authority was given for construction by force account.

March 25, 1907, water was turned through the gates into canal. The principal work of the Reclamation Service was the building of Avalon dam, a loose rock-and-earth-fill type with a reenforced concrete diaphragm through the entire dam, making it impervious to water and burrowing animals. New spillways

and also a new head gate were constructed of reenforced concrete. The canal was double-banked, and the annoying feature of Dark Cañon was crossed by a 6-foot reenforced pressure pipe, thus doing away with the danger from floods. This is probably the first construction of this kind in the Territory. The canal has been relined and repaired, and greater efficiency is now being obtained.

This project was formally opened March 1, 1908, and already over 11,000 acres of the 20,000-acre allotment has applied for water. Crops are looking fine this year; $600,000 has been spent on this project. The farmers who were disheartened when the dam failed in 1904 now seem contented and full of confidence.

The reclaimed tract is situated in Eddy County, ending near the Texas line, in longitude 104°, latitude 32°, at an altitude of 3,100 feet. The Eastern Railway of New Mexico and the Santa Fe system connect this district with its principal markets of Carlsbad, Fort Worth, Denver, and Chicago. The irrigable area, 20,000 acres of very fertile alluvium soil, extends 5 miles to the east and 16 miles to the west of the Pecos River. The range of temperature here is a little greater than that of the Hondo project, being zero to 110° F. The ownership of the 20,000 acres is all private. The farm unit is 160 acres. This land is valued at $50 to $150 an acre, according to location. It produces abundantly alfalfa, corn, cotton, grapes, melons, peaches, and vegetables. The rainfall is 14.02 inches per annum.

The water supply from the Pecos drainage area is annually on an average 150,000 acre-feet. One storage dam, 1,686 feet long and 52 feet high, impounds 15,170 acre-feet of water within an area of 3,240 acres. The diversion dam, of the rock-fill type with concrete core wall, is 1,025 feet long and 50 feet high. The main canal is 3 miles long with a 45-foot bed. The canal on the east side is 5⅓ miles long with a 15-foot bed; the Southern Canal, 7 miles with a 30-foot bed, 10 miles with a 25-foot bed, and 3 miles with a 15-foot bed. The Black River Canal is 6 miles long with a 5-foot bed. The system of lateral canals has a total length of 112 miles with a 3-foot bed.

LEASBURG DIVERSION DAM.

The Leasburg diversion dam, which is in the Rio Grande about 12 miles north of Las Cruces, is a part of the big Engle, or Elephant Butte, project. The object of this diversion dam was to form a permanent head gate for the ditches irrigating the land below in the Mesilla valley. Owing to the erratic changes of the Rio Grande and its shifting character, the water supply for the lands irrigated in Donna Ana County was very indefinite and unreliable. This dam was constructed at a cost of $200,000. Bids were opened on October 16, 1906, and work was started under this contract on November 29, 1906. On account of very high water in the spring of 1907 this work was considerably delayed, but it was finished in time for delivery of

water in the spring of 1908. The dam and the land under it are near the southern border of the Territory, north of El Paso, Tex. This city forms the principal market for the products grown in its vicinity, which are alfalfa, corn, vegetables, melons, and other fruits. Las Cruces, the county seat, and Mesilla Park furnish railroad connections with the Atchison, Topeka and Santa Fe system. The irrigable area consists of 10,000 acres of the bottom land of the Rio Grande, and is all in private ownership. The value of irrigated land in this district ranges from $100 to $150 per acre, but land which will ultimately be irrigated under the Engle project can now be had for prices ranging from $50 to $100 an acre, according to the location and quality of the soil.

The length of the canals under the Leasburg dam is 6 miles. The diversion dam consists of a 600-foot concrete weir and 1,500 feet of earthen embankment. Head gates, waste gates, sand sluices, and drops are all of reenforced concrete, and timber flumes are used for crossing arroyos. As a result of the steady delivery of water the farmers have been very successful during the season. It must not be understood that this dam has reclaimed the land under it, for in truth much of this very land has been irrigated and cultivated from the first advent of the Spanish explorers, if not earlier. Some, however, will be irrigated for the first time.

THE ELEPHANT BUTTE, OR ENGLE, PROJECT.

The main dam for this storage project will form the largest artificial body of water in the world, making a lake over 40 miles long and sufficient to cover 3,125 square miles of ground to the depth of 1 foot.

The irrigating capacity of this gigantic reservoir will be 180,000 acres, and it will water some of the most fertile land under the most favorable climatic conditions in the United States. This large acreage will be apportioned to three districts—110,000 acres in New Mexico, 45,000 acres in the west corner of Texas, and 25,000 acres in Chihuahua, Mexico—as provided in the recent treaty with the Republic of Mexico, wherein the United States guaranteed the delivery of 60,000 acre-feet of water in reparation for the Mexican loss of Rio Grande water formerly utilized. The estimated cost of this project, including the Leasburg diversion dam mentioned above, is $7,200,000.

The aim of the Government to have all such outlays on its part finally borne by the people benefited is carried out in this instance in the following way: For ten years beginning with the year the first crop is raised with water supplied through this system, an annual assessment of $4 per year per acre is to be levied, so that at the end of that period the project will be owned by the people themselves. The

management will be placed in their own hands and the administrative officers elected by them. Of course the Government will exercise official control to the extent of seeing that the agreement with Mexico is kept inviolate.

The site of this dam is 50 miles above Rincon and 9 miles west of Engle, where a natural prominence called Elephant Butte furnishes an ideal location for a big lake. The Assuan Dam in Egypt exceeds this proposed dam in size, but the reservoir formed will be the largest in the world. The base will be solid rock 65 feet below the bed of the river and the dam will be 190 feet above the level of the river bed. It will be 180 feet thick at the bottom, gradually tapering toward the top, but being wide enough there for a wagon road. This width at top is also a precaution for future needs, admitting of more being added to its height.

The capacity of the Engle Reservoir is 2,000,000 acre-feet, and to supply this amount all the unappropriated waters of the Rio Grande have been applied for through the Territorial engineer's office. After once being filled, should no more water flow into it, the reservoir will contain enough to carry the land irrigated under it over two seasons, furnishing sufficient water for the production of crops.

The Rio Grande carries a large amount of silt in suspension. This silt does not come from the headwaters but is acquired through the washing away of the river's banks in its tortuous course. It is estimated by the Reclamation Service that it will take 100 years for this silt to fill up the reservoir. This is one of the most important difficulties confronting the Reclamation Service. Although there is no danger at the present time, future generations may see the huge reservoir filled up. It is suggested that the straightening of the course of the river will, in a short time, rid the river of its silt before it reaches the reservoir site. Continued experience in the improvement of the Rio Grande proves this method to be very practicable and efficacious.

The work on the storage dam is not yet under full headway, but a party has been doing development work there for some time, and a railroad line from a point on the main line of the Santa Fe to the site of the dam is being acquired through right of way proceedings.

LAS VEGAS PROJECT.

This is another project of the Reclamation Service in New Mexico, but it is now on the waiting list, on account of lack of available funds for construction. The acreage contemplated under this proposition is 10,000 acres.

URTON LAKE PROJECT.

The second largest project of the Reclamation Service is the Urton Lake proposition in Chaves County. This has in view the irrigation of 60,000 acres of land, but it is also on the waiting list for lack of funds.

LAWS GOVERNING THE CONTROL AND USE OF WATER.

As has been stated, irrigation was carried on in this Territory centuries ago by the Pueblo Indians, and after the advent of the Spaniards into the valleys and the gradual settlement of the same the newcomers drifted into the crude methods practiced by the Indians. In a great many cases the people still pursue their ancient methods of irrigation. As settlement advanced, the need of a written law on irrigation became more pronounced, but when the legislature took up the matter and enacted its first irrigation laws these were based entirely upon the old customs in vogue on the small community ditches and at a time when the conservation of the water was unthought of, there being always an excess of water and no need of provisions for the apportionment of water between ditches.

These old laws generally provided for three commissioners and a major-domo, all being elected by the community owning the ditch. The major-domo simply turned the water on to the land and off again when the land had received its allotment, which was supposed to be based on the acreage. The major-domo was held responsible for any negligence in the care of the ditch; in case of carelessness the party injured could ask for a committee to inquire into the facts, and if it were found that the major-domo had been negligent they could assess damages, which he would have to pay. This committee was usually composed of ex-commissioners. In most cases the salary of the major-domo was agreed upon between him and the community.

All ditches carried an excess of water, and the extent of land irrigated varied from year to year, according to the fancy of the people. Every landholder under one of these community ditches was assessed every spring so many tareas, computed upon his acreage, for cleaning out the main ditches, a "tarea" meaning a day's work of a man or team. The owner could either hire his assessment work done or do it himself.

As colonization advanced the need of a good up-to-date irrigation law became pressing, and the legislature of 1907 took up the task and passed an excellent irrigation law. One of the difficult questions that arose was how best to utilize all the water and at the same time

protect prior water rights, even when those rights had never been determined. This new law places the apportionment of water in charge of the Territorial engineer, and he is empowered to divide the Territory into districts to coincide with natural drainage areas and to appoint a water master for each district, who has immediate charge of the apportionment of water under the general supervision of the Territorial engineer, such appointment of water masters to be made only after all of the rights on the entire stream system have been adjudicated by the court.

The law also provides that in the adjudication of water rights the court in the district in which the stream is situated shall direct the Territorial engineer to make or furnish a complete hydrographic survey of the entire stream system, and all parties whose claims to the use of water are of record and all others in a position to assert claims, so far as can be ascertained with reasonable diligence, shall be considered and made parties to the suit. Thus the rights and priority of all parties under all ditches in the entire stream system are adjudicated together. Only after all the rights have been adjudicated is it possible to determine if there is water for new appropriations, and such appropriation can only be made with a view of applying to beneficial use all the waters of the Territory. Any person desiring to know the basis of his claim to a water right can have the same, if just, finally established by bringing suit before the judge of the district court and making all persons interested parties to the suit. The court will thereupon issue an order upon the Territorial engineer to make a hydrographic survey of the stream. This the engineer does, making his report to the court, with such recommendations as may be deemed advisable. After final adjudication of the rights in a stream system the Territorial engineer can appoint a water master at the request of the majority of the water users.

This law further provides that in the adjudication of rights or the granting of permits to appropriate water the quantity allowed shall not be in excess of 1 cubic foot per second for every 70 acres of land irrigated, and in no case is it permissible for an irrigator to waste water. The act declares that the water is appurtenant to the land, but provides a way by which it may be changed to other lands or to a different beneficial use in case the water can be used to better advantage.

All new water rights are acquired by making application for a permit from the Territorial engineer to appropriate specified public water. After the application has been received, together with the plans and specifications, and these are found satisfactory, then if in the opinion of the engineer there is unappropriated water available, he will authorize the applicant to publish for four consecutive weeks

in some newspaper of general circulation in the district notice of his intended appropriation, also stating the time when the engineer will take up the application for consideration. Thus all parties are notified of any intended appropriation and given a chance to protest against the granting of an application in case they may think it would interfere with any of their prior rights. On or after the date specified the Territorial engineer will determine, from the evidence presented by parties interested and from surveys and records, whether there is any unappropriated water available; if so, and if said project would be to the public interest, the engineer will approve the application, stating the time at which the applicant will have to commence construction work and the time within which he must put the water to a beneficial use, thus not tying up unappropriated water for an indefinite length of time. At the time set for the putting of the water to a beneficial use the engineer will issue a license to that amount of water only which actually is being used beneficially at the time of his inspection of the works.

The method of distributing the water from the ditches and canals is left to the owner of the canal, save that in case of an appeal from a majority of the water users or if the Territorial engineer thinks it is to the best public interest a water master can be appointed, who will then have charge of the distribution from the canal to the individual owners.

The law makes the basis of a water right beneficial use of the water; hence appropriation of water is permissible for not only irrigation purposes, but for power, mining, and domestic purposes, thus rendering possible the use of water very often several times over.

Most irrigation companies and water users' associations in the Territory distribute water from their ditch systems on the rotation plan; that is, each landowner takes a head of water in his regular turn and keeps the water for a certain length of time regulated by the extent of land for which he has a water right. This rule has been resorted to by most associations in order to procure a more constant flow of water in their canals, which is quite necessary, especially if the system has no storage. Since there are times when more water is needed than at others, it seems more practical to deliver water upon an order from the irrigator, and where there are storage facilities this could be done to a reasonable extent if orders were made a sufficient time in advance of need to permit the delivery.

Experience in delivering water to a large number of small-farm owners shows that unless the water is sold by quantity the above rule will not work satisfactorily, because of a lack of knowledge of irrigation farming which is especially prevalent in a new country among new settlers inexperienced in irrigation. It is natural in an irrigated

country where water is sold by the season for a farmer to presume that when his crop is not doing well it is for lack of water and immediately to send in a call for more.

It is apparent that the cost of delivery of water per acre is greater than it should be, owing to the excessive quantities of water used. This cost ranges for the direct gravity system 25 cents to $1 an acre by storage, and 60 cents to $1.35 for gravity delivery. Pumping water for irrigation costs 50 cents to $2.50 per acre. This wide range is to be accounted for by the fact that where a man pumps water the cost is based upon the quantity used. The pumper will economize, as he feels the direct cost. The result is that pumping by private plants is often much cheaper per acre irrigated than irrigation by the gravity method, and also that the crops raised are far superior in all points.

The writer is inclined to believe that from the standpoint of the water user, the water users' association, or the company, and the general public the cost of water should be based on the quantity used, thus accentuating the necessity of economizing water and of studying in its higher phases the question of irrigation farming.

Economy in irrigation brings about the best results. It is not a saving of labor, for decreasing the amount of water increases the necessity for cultivation, but this is the secret of success in irrigation farming rather than unrestricted application of water. Overirrigation destroys the farmer's own land and eventually adjoining lands also, for it results in the raising of the water table to the surface of the soil and on the lower land above the surface. The sun evaporates the pure water, leaving the impurities contained in solution—the alkali—and even when drained it is either alkalied land or overirrigation has puddled the soil, so that it is not susceptible to water or cultivation and capable of the growth of crops. Remedies have to be resorted to in order to loosen the soil and supply it with humus and nitrogen. The water user not only ruins his own land and that of his neighbor, but uses up water that ought to be applied to other lands or returned to the public water supply, subject to further appropriation on land less favored in location but as rich in soil ingredients.

THE SETTLEMENT OF LANDS UNDER IRRIGATION.

To every prospective irrigation farmer there should be given a thorough understanding of the obstacles to be met and difficulties to be overcome before the benefits of the practice can be regularly obtained and permanently enjoyed. He should know that to prepare his land for irrigation is more expensive than cultivation is in the rainfall States, should he come from that section, where crops are

merely sown in prepared ground and left to the elements until harvest time. If the new settler hopes to make a success of farming in this section he must learn that the land must be leveled in such a manner that it will irrigate easily and evenly and that there must be means of conveyance for the water to reach the land. The ditches, canals, pipes, flumes, or other conduits must be built with regular grades suitable to the natural conformation of the land and calculated to get the water as quickly as possible and with as little waste as possible to the land. In some ditches the soil is such that the water can flow quickly without cutting the sides of the ditch, but as a general thing diversion boxes must be placed in the ditches where they branch off in order to keep the water in its prescribed course.

METHODS OF IRRIGATION.

The principal methods of irrigation in New Mexico are the furrow, flooding, and check systems.

When the furrow system is desired the ground is leveled and smoothed off evenly and furrows are plowed following the contour of the land. Sufficient grade should be given these furrows so that the water will flow slowly and evenly through them without overflowing or washing away the soil. This method admits of cultivation soon after irrigation whereby with the use of a harrow a soil mulch is quickly formed before evaporation has set in.

In the flooding system the ground has to be all leveled to an even grade, for if there are any high spots they will not receive sufficient water when irrigated, while the low spots will receive too much and the plants become rotted by the standing water and the soil waterlogged eventually. The water is conveyed by ditches onto the ground where it is allowed to spread out over the land, being held in proper confines by borders.

In the check system the ground is leveled, with borders on all sides, thus forming small rectangular checks, generally half an acre in extent, into which the water is turned, flooding and covering the entire check with about 4 inches of water. When the soil has received sufficient water the border of the next check along the route of the distributing ditch or lateral is cut and the next lower check is filled as the preceding, and so on.

The cost of preparing the soil for irrigation varies according to natural conditions. Some land lying almost suitable for irrigation by the furrow or flooding system in its natural state would cost, outside of general preparation of the soil for seeding and the bordering or furrowing, not to exceed $2 or $3 per acre, while other ground would cost $25 to $30 per acre to level. This excessive cost is on very

uneven ground, such as places where sand dunes have been formed or where ridges have to be lowered in order to be able to get desired grades. However, the average cost of grading the soil for irrigation purposes ranges from $3 to $8 per acre. Bordering and furrowing cost 50 cents to $1 per acre.

In addition to leveling, bordering, and furrowing, most land has first to be cleared. Greasewood or sagebrush land can be cleared very cheaply, as it is generally level, so that the brush can be broken down by dragging a heavy log over it, then the land can be plowed. Mesquit, cedar, and piñon land costs more to clear. On mesquit land the cost is largely that of grubbing out the roots, these roots being large and crooked; but usually in localities where mesquit grows abundantly there is very little other timber for fuel and the roots are sold for wood, generally bringing from one-third to one-half of the cost of grubbing. Contracts for grubbing per acre vary from $2 to $10 an acre. On cedar and piñon land the fuel and fence posts gathered generally pay for the clearing.

Farm ditches are generally made by plowing the line of ditch, then plowing and V-ing the last plowing, thus making a V ditch sufficient for farm use and at a cost of about $10 to $15 per mile.

The cost of fencing depends on the kind of fence built. A large proportion of the fence in this country is barbed wire, which can be built for about 30 to 50 cents per rod. However, a fence that is now coming more into use is the woven-wire fence, which would cost already built $1 to $1.20 a rod.

Merely to state in figures what the actual cost of this or that is would be absolutely useless, for the prices of labor or the various commodities are not the same under the different conditions in the Territory; nevertheless, it seems advisable to state briefly the average cost of such work, based upon experience and observation, and in estimating the amount of capital necessary for a beginner in this country, besides the cost already explained for preparing the soil, $500 worth of stock, $250 of implements, and $1,500 for the construction of a suitable house and other buildings would serve at least as a starter in commencing farming.

All of this preparation requires considerable time and labor, yet when permanently done 1 acre of irrigated land, together with its water right, is worth several acres of the best land under rainfall conditions. It is a saving in the end for the new farmer to be equipped with plenty of capital at the start. With this he can provide himself with the necessary implements and buildings in order to begin his new life on a solid working basis, systematize his farm life, and handle in an up-to-date manner its manifold returns. By

some it is considered better to borrow the necessary capital to start right than to barely eke out a living by the use of poor implements in order to save up for better ones. The cost of the extra outlay can be saved in a few years. It is the ultimate aim of every New Mexico farmer to build himself a home and to surround himself with modern conveniences, for this is the reward of modern, scientific agriculture.

The principal implements necessary for irrigation farming, in addition to those needed under ordinary conditions, are machines for leveling ground and making ditches, borders, and furrows. By "borders" are meant ridges made around certain areas to impound water during irrigation so that it will soak into the soil instead of running off. Each section surrounded by these borders is submerged in turn to a depth of 3 or 4 inches, and then the current turned into another section. This mode of irrigating, characteristic of the Southwest, is used for the irrigation of field crops, such as alfalfa and grains, while orchards and crops set in rows are irrigated by ditches and furrows. The ordinary farmer can, aside from plows and scrapers, make implements for leveling, bordering, and similar operations, that will serve the purpose very well, in this way cutting down expense, but in no case should he try to cut down the thoroughness of his work. The land should be put in perfect shape at the beginning, as a correct start will pay for the extra effort in reduction of the cost of farming and in greater returns from crops. Successful irrigation means intensive farming. It is essential that the farm be properly prepared for even irrigation, and no farmer need expect success unless it is so prepared. A properly prepared and conducted 20-acre irrigated farm can net the owner more than an ordinary 80-acre farm.

Irrigation farming is the result of scientific research and individual experiment. In addition to having his farm properly prepared the agriculturist must learn to take care of the soil. The home builder should provide himself with good teams, a cow or two, and other stock, modern implements used in ordinary farming, such as good plows, harrows, cultivators, shovels, seeders, harvesters, and vehicles, and should build a substantial and comfortable house before settling down in earnest to progressive farming.

The temperature in this section of the United States is rather high and the ground rarely freezes to any depth. Thus the soil becomes hard, and deep fall plowing is quite necessary in order to take the place of the loosening of the soil that is generally done by freezing in northern climates. Plowing puts the soil in shape to receive the fall and winter moisture. Irrigation has a greater tendency to run the soil together than rain.

FUTURE DEVELOPMENT IN IRRIGATION FARMING.

In the future, to progress materially with the increase of population, increasing values of land, and the greater use of and demand for water, development in irrigation must necessarily proceed upon the following lines: (1) Increased duty of water; (2) more intensive farming; (3) scientific study of seepage, evaporation, and soil qualities; (4) development of storage, power, and pumping; (5) adjudication of water rights; and (6) official collection of data.

(1) From the earliest record of irrigation up to the present time the method of irrigation in some localities has been wanton and extravagant in the extreme. This constitutes the most vital line upon which development must proceed. This does not appear on the surface to be an issue at present, owing to the large quantities of unappropriated water in our principal streams, but with the present rate of growth in population every available homestead will have to support a family, and then this will become the most important factor in agricultural progress. On three or four of our stream systems this has already come to pass, and applications for permits to appropriate have already been filed far in excess of the supply.

The wholesale flooding of crops not only injures the growing plant itself, as has been proved by experiment, but very surely water-logs the land and renders it alkaline unless the slope is perfect, not counting the scarcity of water the neighboring irrigators experience as a result. At some places in California the duty of water is said to have been raised to 1,000 acres per cubic foot per second. Taking into consideration the proportional amounts of land and water supply in New Mexico, it will be seen that something like this will ultimately have to be attained. When water becomes scarce a study of the crops yielding the best net returns will be considered. The study of soil, atmosphere, drainage, night irrigation, and underground application of water are problems to be faced in the future. Such a study of night irrigation will reveal not only the saving of water, but the means of avoiding the caking and cracking of the soil under the hot rays of the sun, which injures the stems of growing plants. The common opinion that if so much water does good, double the quantity will double the benefits, will be dispelled by an unbiased trial.

(2) The production of alfalfa plays a leading part in New Mexican agriculture. This crop has proved itself a sure money getter. It is easy to handle and the market is always good, and it demands a minimum amount of labor for the returns. It has been aptly called "the lazy man's crop." When, however, many settlers from other States take up land along a particular stream, the supply of water to each individual becomes less and the value higher. A point will